21 May 2004

Chuck Farrar

RE: Potential Project for LADSS
    Baseball – Bat Impact/Response Model Development

At UMASS Lowell, the university has a Baseball Research Center within the Mechanical Engineering Department. This Center evaluates wood and aluminum bats for certification for baseball use. Some work has been done to characterize the bat dynamically but there are a few potential modeling concepts that have never been explored – these are in relation to use of experimentally derived modal data to develop (and/or tweak and tune) a bat for dynamic response modeling applications.

Currently several other people (Allan at UIUC and Russell at Kittering and others) have developed models that try to address the bat-ball interaction with models that consist of one or two dof. A few schematics are shown below from their published journal work. There is a belief that the hoop modes of the aluminum bat provide a "trampoline" effect on the barrel.
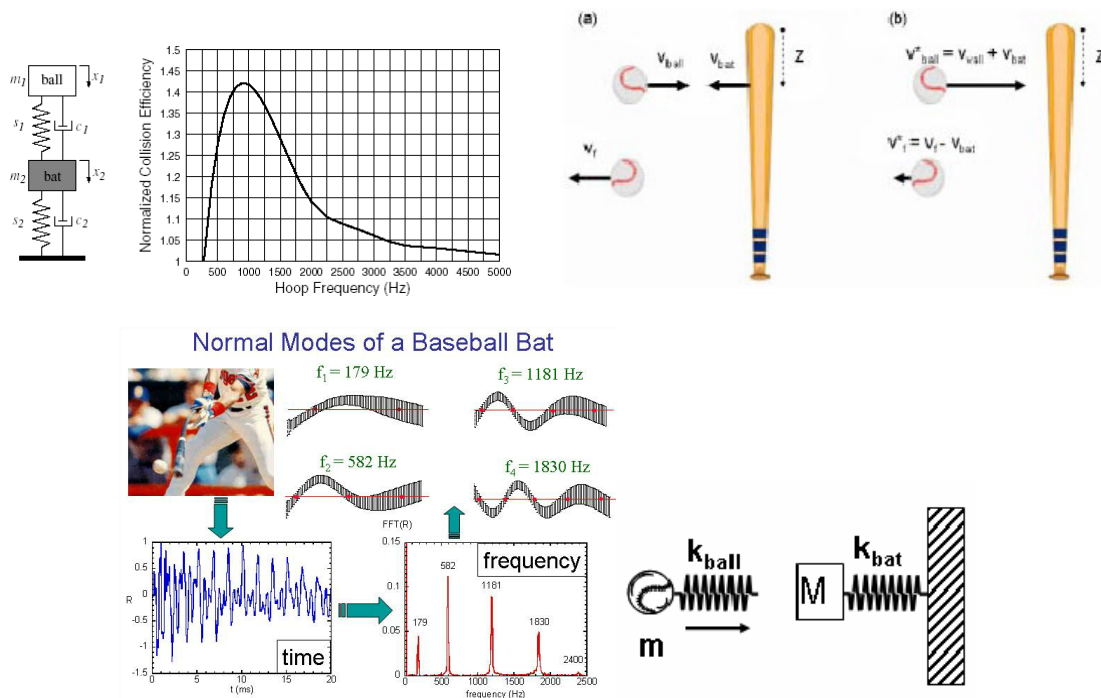
These models miss a lot of the overall dynamics with these simplistic approximations. The hoop effect is likely to be very spatially dependent and a simple model cannot address this.

THOUGHTS FOR A BETTER MODEL USING ANALYTICAL REDUCED MODEL CONCEPTS ALONG WITH EXPERIMENTALLY DERIVED PHYSICAL MATRICES FROM TEST DATA

Develop a finite element model and an experimental model for the bat. Tests – analysis – correlation and some updating if necessary. Use the test data at limited numbers of dof to develop a better MCK representation of the bat to capture the dynamics more correctly allowing for some spatial dependency. Use reduced analytical models and experimental models to develop this representation. Then perform an impact study to determine the ball exit velocity as a function of location on the barrel using the MCK model developed from experimental modal data.

This is a very good overall project with some significant effort to be devoted to experimental testing, analytical modeling, reduced model approximations, correlation, updating, impact/momentum applications. (Much of the underlying theory of test-analysis-correlation and development of reduced models comes from Avitabile's dissertation – many of the concepts in that thesis can be extended to the solution of this problem. Some of these extensions were identified to last year's group working with Matt Bemmet. Some additional notes for the suggested approach are on the attached sheets)

SUPPORT FROM UMASS LOWELL BASEBALL RESEARCH CENTER

Jim Sherwood is willing to provide equipment for this effort as well as any data that already exists from the bat hitting machine. Sherwood and Avitabile teach Mechanical Engineering courses together and have had several students work on common projects and theses.

Let me know if you think this is a suitable project. I am expecting that there are some direct parallels to missile impact problems that may utilize some of what is developed here.

MODE 1
MODE 2
MODE3
MODE 4
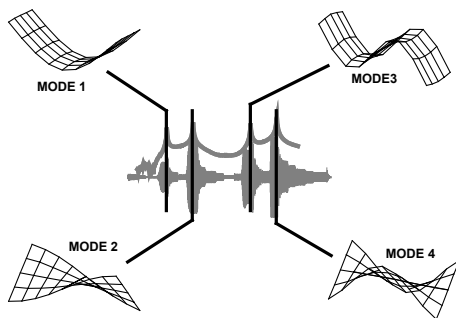
Sincerely,

Dr. Peter Avitabile
Director, Modal Analysis and Controls Laboratory
University of Massachusetts Lowell
One University Avenue
Lowell, Massachusetts 01854
peter_avitabile@uml.edu
978-934-3176

TASKS TO BE PERFORMED AS PART OF THIS LADSS PROJECT EFFORT

1) Develop finite element models of aluminum and wood bat (some of these models already exist from student work in the UMASS Lowell Baseball Research Center and can be used as a guide or reference.

2) Perform experimental modal tests on the bat and develop a good modal model of the bat

3) Correlate the analytical and experimental models (tweak and tune if necessary)

4) Develop reduced mode approximations of the bats using SEREP and Hybrid techniques

$$[M_a] = [T]^T [M_n][T] \; ; \; [K_a] = [T]^T [K_n][T] \quad \text{(General Reduction Approach for [T] transformation)}$$

$$[T_U] = [U_n][U_a]^g \quad \text{(O'Callahan/Avitabile Method)}$$

$$[T_H] = [T_S] + [[T_U] - [T_S]][[U_a][U_a]^T [T_U]^T [M_n][T_U]] \quad \text{(Dan Kammer's Method)}$$

5) Develop reduced model approximations using experimental data; correlate and compared to reduced FEM

$$[E]^T [M][E] = [\overline{M}] = [I] \; ; \; [E]^T [K][E] = [\overline{K}] = [\Omega^2] \quad \text{(Basic statement of modal representation)}$$

$$[E^g]^T [I][E^g] = [M] \; ; \; [E^g]^T [\Omega^2][E^g] = [K] \quad \text{(Rough approximation approach)}$$

Further improvement of these results in

$$[M_I] = [M_S] + [V]^T [I - \overline{M}_S][V] \; ; \; [\Delta M] = [[\overline{M}_S]^{-1}[U]^T [M_S]^T]^T [\Delta \overline{M}][[\overline{M}_S]^{-1}[U]^T [M_S]]$$

$$[K_I] = [K_S] + [V]^T [\grave{} \omega^2 + \overline{K}_S][V] - [[K_S][U][V]] - [[K_S][U][V]]^T$$

6) Identify bat-ball interaction model
Extend work of Allan and Russell to include more than 1 dof to characterize the bat using either the analytical reduced physical models and/or the experimentally derived reduced order models to characterize the bat dynamics to include both global bending and local barrel dynamics

(The work of Allan and Russell has not been reviewed as yet. Papers are available and both individuals seem to be very easy to work with. This needs to be researched to determine what response models/approaches were actually employed by these two individuals)

7) Correlate predicted response with data from baseball hitting machine at UMASS Lowell

References (baseball references included – known refs provided later - Avitabile, O'Callahan, Kammer)
Nathan Allan   http://www.npl.uiuc.edu/~a-nathan/pob/
Paper http://www.npl.uiuc.edu/~anathan/pob/AJPNov2000.pdf
Paper http://www.npl.uiuc.edu/~a-nathan/pob/AJP-Feb2003.pdf

Dan Russell   http://www.gmi.edu/~drussell/
Paper http://www.kettering.edu/~drussell/Publications/hoopfreq.pdf
Paper http://www.kettering.edu/~drussell/Publications/trampoline.pdf